Verification Case Studies within the 12 km North American Land Data Assimilation System (NLDASE) Project

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NLDASE Project Overview

Land surface conditions from uncoupled LSMs forced by observations are free from many of the biases which affect closed, coupled systems, and are well-suited for NWP model initialization. The NLDASE project seeks to assess the impact of such initialization on NCEP's 12km coupled workstation Eta model (Black, 1994). Featuring multiple LSMs and assimilating multiple land surface quantities, this system will serve to supply the Eta model with accurate, unbiased and uncoupled initial land surface conditions on its native Arakawa E grid. Project components include: 1) Generation of land surface states over the North and Central American domain, with and without application of land data assimilation techniques, 2) Initialization of the NCEP workstation Eta model with uncoupled NLDASE states and internally cycled Eta land surface states, 3) Execution of ensemble model runs using NLDASE and Eta modeling system.

Eta Model Initialization

•Experiments are assessing the impact that NLDASE initialization of Eta model land surface states has on short- to medium-range forecasts (Figure 1)

•Validation of Eta model forecasts is occurring over the standard NCEP Forecast Verification System (FVS) (Brill, 1999) regions pictured in Figure 2.

•*All initial atmospheric conditions and boundary conditions are identical between NLDASE Eta model simulations. The only difference lies in the initial land surface conditions that are used (**LIS1, LIS2, LIS3** and **NCEP** runs discussed below)*

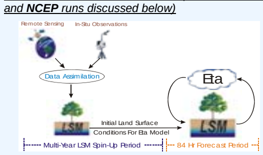

Figure 1. NLDASE initialization strategy. Forced by observation and model-based data, and constrained by data assimilation, NLDASE will generate several years of land surface output which will be used to initialize the Eta model's land surface states.

Land Surface Modeling Component

• NLDASE research is based at NASA GSFC with support from NOAA NCEP

• Noah, Mosaic, and CLM LSMs will be used

• Hourly, uncoupled LSM output is being generated on the 12km Arakawa E grid used by the operational Eta model for the period from 2000-2003.

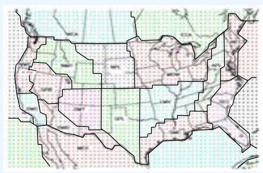

Figure 2. Validation of NLDASE Eta simulations is performed over the standard NCEP Forecast Verification System (FVS) regions pictured above.

NLDASE Benchmarking Effort

• An ongoing benchmarking effort seeks to determine the impact on Eta model forecasts of using initial land surface conditions from three different NLDASE-Noah LSM simulations:

- **LIS1** run--with NLDASE forcing.
- **LIS2** run--with NLDASE forcing and MODIS snow cover assimilation (5 mm update amount).
- **LIS3** run--with NLDASE forcing and MODIS snow cover assimilation (10 mm update amount).

• Comparisons are performed against Eta model forecasts produced with **NCEP** operational initial land surface conditions (Figure 3).

• The benchmark covers May 1-10, 2003, which featured a massive severe weather outbreak over the central and eastern United States (details of event can be found in Hamill et al. (2005).

• A total of 80 Eta model runs were conducted out to 84 hours (4 sets of initial conditions, 2 cycles per day for 10 days).

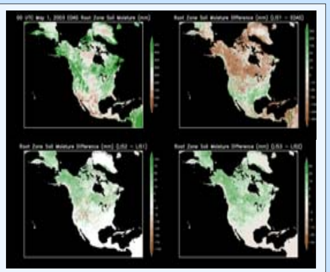

Figure 3. Sample EDAS root zone soil moisture (mm) field (upper left) and associated root zone soil moisture differences between EDAS and the NLDASE uncoupled simulations.

Benchmarking Results

All Surface Forecasts

	T2ML1	T2ML2	T2ML3	RH2ML1	RH2ML2	RH2ML3	V10ML1	V10ML2	V10ML3
00Z East Bias	13.72	17.54	21.05	56.59	68.30	78.21	4.66	4.48	4.31
00Z West Bias	10.94	13.42	16.12	12.91	13.64	14.90	-7.22	-7.22	-7.69
12Z East Bias	-0.31	2.72	7.22	42.64	51.95	60.34	4.16	3.85	3.38
12Z West Bias	6.63	8.63	12.11	14.42	15.25	17.03	-6.85	-6.56	-6.13
00Z East RMSE	2.31	2.31	2.44	4.49	4.45	4.51	1.03	0.95	0.98
00Z West RMSE	1.66	2.04	2.36	4.72	5.01	5.45	0.66	0.63	0.73
12Z East RMSE	2.42	2.67	3.09	5.28	5.36	5.38	0.86	0.84	0.57
12Z West RMSE	1.60	2.04	2.26	5.61	5.92	6.34	0.65	0.67	0.02

Table 1. Percent improvement in bias and RMSE of LIS1 (L1), LIS2 (L2), and LIS3(L3) runs versus control simulation for 2m temperature (T2M), 2m relative humidity (RH2m), and 10m wind speed (V10M).

All Precipitation Forecasts

	0-24HPL1	0-24HPL2	0-24HPL3	24-48HPL1	24-48HPL2	24-48HPL3	0-84HPL1	0-84HPL2	0-84HPL3
East Bias	-7.79	-8.23	-6.93	0.01	0.01	0.02	4.02	4.02	5.80
West Bias	27.36	24.53	24.53	-0.02	-0.01	0.01	-217.65	-123.53	-52.94
East ETS	0.40	0.40	0.54	-0.25	-0.12	0.00	0.12	0.12	0.00
West ETS	0.25	0.25	0.13	0.72	0.60	0.60	0.24	-1.77	-1.88
East POD	-0.18	0.00	0.00	-0.16	-0.16	0.32	0.16	0.16	0.16
West POD	1.05	1.05	0.90	2.38	1.96	1.96	0.68	0.68	0.82
East FAR	2.53	2.53	2.34	-0.81	-0.49	-0.33	0.17	0.17	0.00
West FAR	-11.91	-0.76	-0.95	0.16	-0.16	-0.31	-0.46	-6.49	-6.65

Table 2. Percent improvement in bias, equitable threat score (ETS), probability of detection (POD), and false alarm ratio (FAR) scores of LIS1 (L1), LIS2 (L2), and LIS3 (L3) runs over control simulation for 0-24 hour, 24-48 hour, and 0-84 hour forecast periods.

Verification Case Studies From Benchmarking Effort

The NCEP FVS results from the entire 10-day benchmarking period indicated that the surface temperature and relative humidity fields were most sensitive to the use of uncoupled NLDASE land surface states (Table 1), while the impact on precipitation forecasts was mixed and generally small (Table 2). The FVS benchmark metrics are frequently utilized by NCEP to evaluate the Eta model's performance, and provide copious amounts or useful information as to where weakneses are present in the forecast guidance. However, these benchmarks contain multiple forecasts and are regional in nature (Figure 2); therefore, they are unable to depict the impact that an individual forecast may have within a specific region. A selection of individual forecast FVS statistics, surface station time series, and regional observations are presented herein to highlight the impacts that NLDASE initialization has on individual Eta forecasts of surface temperature, relative humidity, and precipitation. Sources of data utilized in this study are surface observations (land and water) from the Global Telecommunications System (GTS), Climate Prediction Center (CPC) Daily Precipitation Analyses (Higgins et al., 2000), and NCEP Stage II /IV Hourly Precipitation Analyses (Lin and Mitchell, 2005).

Eta Forecasts Initialized 12Z May 3rd 2003

Surface Forecasts

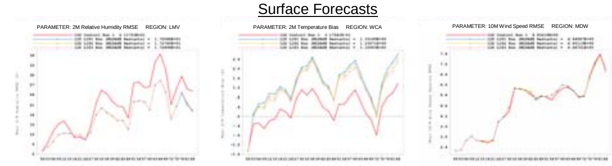

Figure 4. FVS output for all four Eta forecasts initialized on 12Z May 3 2003. From left to right: 2m relative humidity RMSE in the LMV verification region, 2m temperature bias in the WCA verification region, and 10m wind speed RMSE in the MDW verification region. In general, the NLDASE forecasts were very similar to one another and at times differed greatly from the control forecast. The NLDASE forecasts showed significant improvement in forecasts of 2m temperature and relative humidity in most regions (exception depicted in WCA), while forecasts of 10m wind speed remained relatively unchanged.

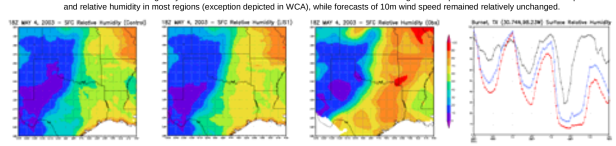

Figure 5. Comparison of 2m relative humidity forecasts over the southern central US. The LIS1 run exhibits significant improvement over the control run when compared to surface observations.

Precipitation Forecasts

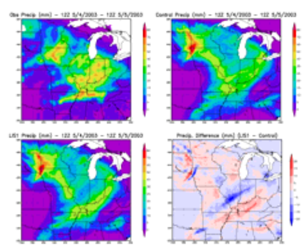

Figure 6. Comparison of 24 – 48 hr precipitation forecasts in the Midwest US with observations. Large differences in precipitation emerge between the two forecasts within this verification region. LIS2 and LIS3 forecasts were not included in this analysis because they differed only very slightly from the LIS1 forecast.

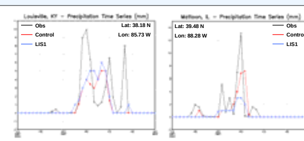

Figure 7. 24 – 48 hr precipitation time series for Louisville, KY, and Mattoon, IL. The LIS1 forecast outperforms the control run at Louisville in terms of total precipitation forecasted. However, LIS1 under-forecasts precipitation at the Mattoon location.

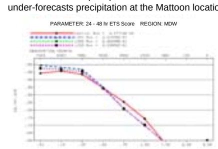

Figure 8. 24 – 48 hr equitable threat score for all four forecasts in the MDW verification region. The NLDASE initialized runs show improvement in forecasting the smaller precipitation amounts; however, they misplace the larger precipitation amounts.

Eta Forecasts Initialized 00Z May 9th 2003

Surface Forecasts

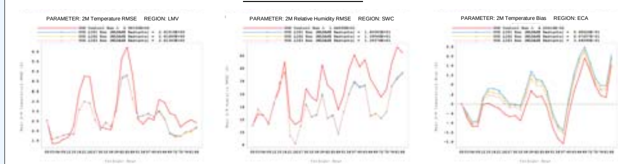

Figure 9. FVS output for all four Eta forecasts initialized on 00Z May 9, 2003. From left to right:, 2m temperature RMSE in the LMV verification region, 2m temperature bias in the SWC verification region, and 2m temperature bias in the ECA verification region. Similar to Figure 4, the NLDASE forecasts showed significant improvement in the 2m temperature and relative humidity fields in most regions, with the exception of eastern and western Canada.

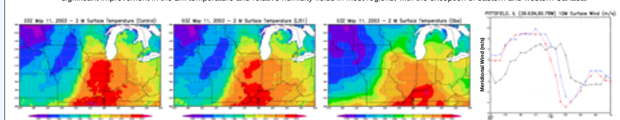

Figure 10. Comparison of 2m temperature forecasts over the Midwest US. The LIS1 run exhibits significant improvement over the control run when compared to surface observations. The LIS1 forecast more accurately depicts the timing of a cold front passage through Pittsfield, IL.

Precipitation Forecasts

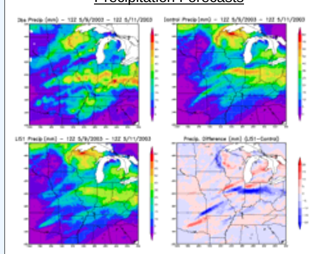

Figure 11. Comparison of 48 hr precipitation forecasts (valid at 12Z May 5, 2003) in the Midwest US with observations. Again, large differences in precipitation emerge between the two forecasts within this verification region. The control run better predicts the heaviest precipitation amounts in Illinois and Indiana, however, the LIS1 simulation exhibits slightly better precipitation placement.

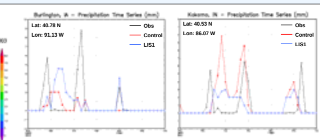

Figure 12. 24 – 60 hr precipitation time series for Louisville, KY and Mattoon, IL. The LIS1 forecast outperforms the control run at Burlington in terms of total precipitation forecasted but exhibits degraded timing of precipitation. Conversely, the LIS1 forecast severely underestimates the precipitation timing and amounts at Kokomo.

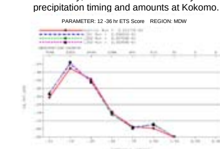

Figure 13. 12 – 36 hr total precipitation equitable threat score for all four forecasts in the MDW verification region. The NLDASE initialized runs show slight improvement in forecasting select precipitation amounts.

Summary

• Large differences emerge between the NLDASE initialized forecasts and the control forecast when examining individual forecasts.

• In general, the largest differences in forecasts came between the NLDASE simulations as a whole and the control forecast.

• Surface temperature and relative humidity frequently benefited from the uncoupled initialization approach.

• In some cases, the timing and magnitude of fronts/dry-lines was impacted (both positively and negatively) by the use of NLDASE land surface states.

• NLDASE-based forecasts featured improved precipitation magnitude or timing at some locations and degraded precipitation timing or magnitude at others, yielding mixed results overall.

• Future work will include upper air verification and detailed examination of how the NLDASE initial conditions improved and or degraded the forecasts.

References:

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Acknowledgements:

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